NUMERICAL SIMULATION OF TUFF DISSOLUTION AND PRECIPITATION EXPERIMENTS: VALIDATION OF THERMAL-HYDROLOGIC-CHEMICAL (THC) COUPLED-PROCESS MODELING

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As part of an ongoing effort to evaluate THC effects on flow in fractured media, we performed a laboratory experiment and numerical simulations to investigate mineral dissolution and precipitation. To replicate mineral dissolution by condensate in fractured tuff, deionized water equilibrated with carbon dioxide was flowed for 1,500 hours through crushed Yucca Mountain tuff at 94°C. The reacted water was collected and sampled for major dissolved species, total alkalinity, electrical conductivity, and pH. The resulting steady-state fluid composition had a total dissolved solids content of about 140 mg/L; silica was the dominant dissolved constituent. A portion of the steady-state reacted water was flowed at 10.8 mL/hr into a 31.7-cm tall, 16.2-cm wide vertically oriented planar fracture with a hydraulic aperture of 31 microns in a block of welded Topopah Spring tuff that was maintained at 80°C at the top and 130°C at the bottom. The fracture began to seal within five days.

A 1-D plug-flow model using the TOUGHREACT code developed at Berkeley Lab was used to simulate mineral dissolution, and a 2-D model was developed to simulate the flow of mineralized water through a planar fracture, where boiling conditions led to mineral precipitation. Predicted concentrations of the major dissolved constituents for the tuff dissolution were within a factor of 2 of the measured average steady-state compositions. The fracture-plugging simulations result in the precipitation of amorphous silica at the base of the boiling front, leading to a hundred-fold decrease in fracture permeability in less than 6 days, consistent with the laboratory experiment.

These results help validate the use of the TOUGHREACT code for THC modeling of the Yucca Mountain system. The experiment and simulations indicate that boiling and concomitant precipitation of amorphous silica could cause significant reductions in fracture porosity and permeability on a local scale. The TOUGHREACT code will be used to evaluate larger-scale silica sealing observed in a portion of the Yellowstone geothermal system, a natural analog for the precipitation-experiment processes.